Wind and Wind Stress Measurements in HiRes

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LONG-TERM GOALS

The long-term goals are to further the understanding of air-sea interaction processes including momentum, heat, water vapor, surface and boundary layer dynamics under various meteorological and oceanographic conditions.

OBJECTIVES

The objectives of this grant are to measure and analyze the wind, wind stress and associated quantities at sea in the High Resolution Air-Sea Interaction DRI (HiRes). The practical objectives of Hi-Res are the determination of how well ship-based radars can measure the phase-resolved surface wave field (PRSWF), testing the skill of highly-nonlinear numerical surface wave models to predict the evolution of the PRSWF, and the incorporation of ocean wave effects into models of the Marine Atmospheric Boundary Layer (MABL).

APPROACH

The HiRes grant started in April 2008. The initial phase of the research was to design the experimental system to be conducted on R/P FLIP. The penultimate experiment was conducted in June 2010 from FLIP, which was moored off the Northern California coast. Data from a past experiment are also being analyzed with respect to processes relevant to HiRes.

WORK COMPLETED

The main cruise on R/P FLIP was performed in June 2010. The UCI meteorological mast was deployed with sensors to meet the objectives of the HiRes DRI. These included:

1. Sonic anemometers for three-dimensional mean and turbulent winds
2. Leosphere Windcube for wind in upper regions of MABL.
3. Propeller-vane anemometer for mean winds
4. Thermistors for air temperature in fan-aspirated solar radiation shields
5. Precision barometers for mean and fluctuating pressure (T. Hristov, Johns Hopkins)
6. Modified Krypton hygrometer for fast-response humidity

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7. Oxford GPS/inertial navigation and reference unit to measure FLIP's motion
8. National Instruments data system (105 signals) with GPS module providing the accurate timestamp
9. Wave lasers and resistance wave wires for wave height measurements

RESULTS

Mass, momentum and energy fluxes between the atmosphere and the ocean play a crucial role in air-sea interaction. Currently fluxes are represented by coefficients that depend on averaged wind and wave variables. In moderate to high wind and wave conditions, the data sets for this representation are incomplete and new parameterizations relevant to wind-wave models are sought. With these long term goals in mind, measurements were made during the field experiment, HiRes on Research Platform R/P FLIP in June 2010. These measurements included wind, pressure, temperature, fluxes and wave in the separate regions of the MABL. Figure 1 shows an image of R/P FLIP moored with instrumentation deployed.

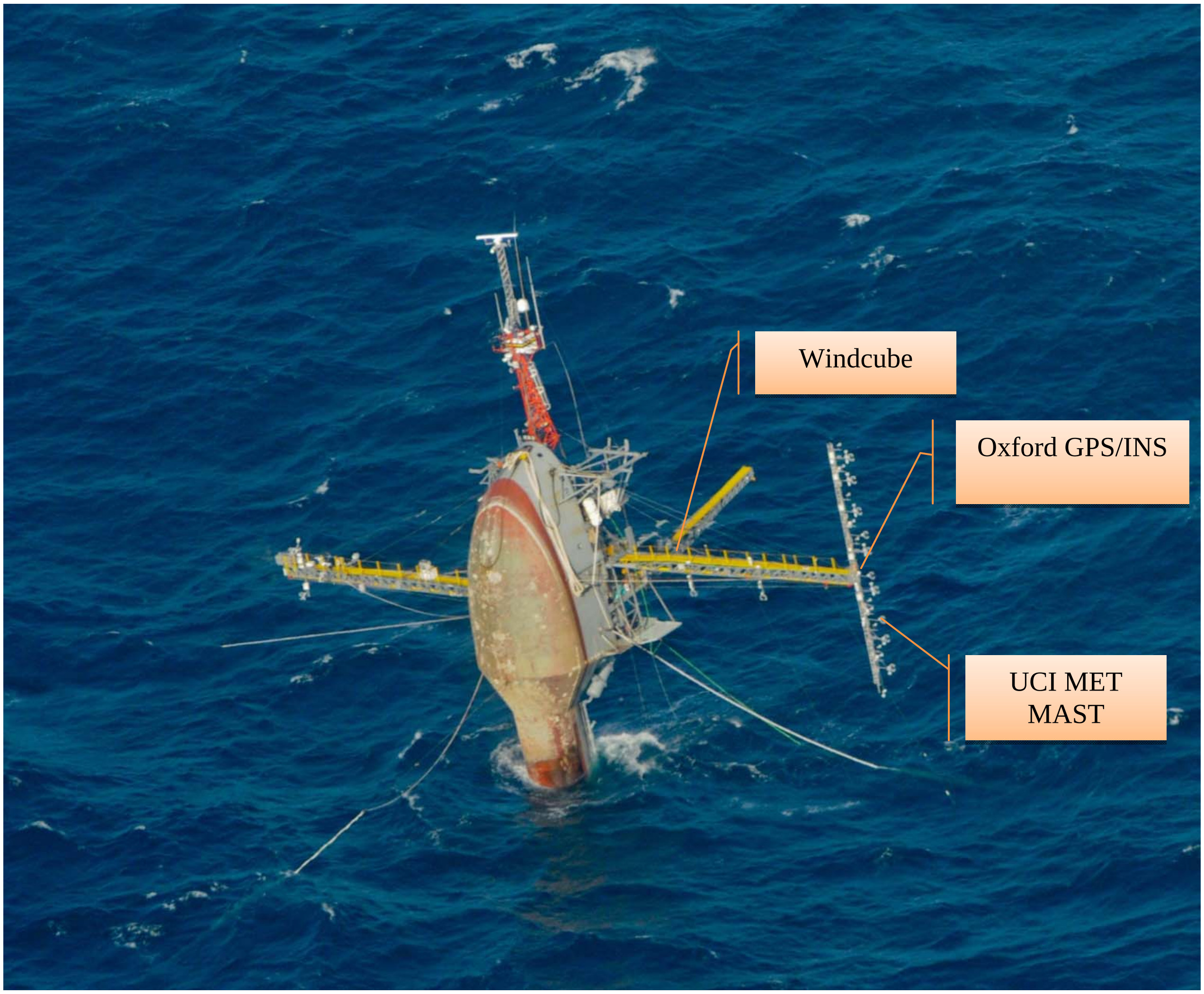

Figure 1 : Moored R/P FLIP off coast of Northern California during HiRes DRI. For scale the UCI mast is 50ft (~17m). (Photo courtesy of Leonel Romero, SIO)

The ocean state where R/P FLIP was moored, can be seen from Figure 2 which shows data from the nearby NDBC Buoy 46013 at 38.242N, 123.301W for the dates R/P FLIP was at the HiRes site.

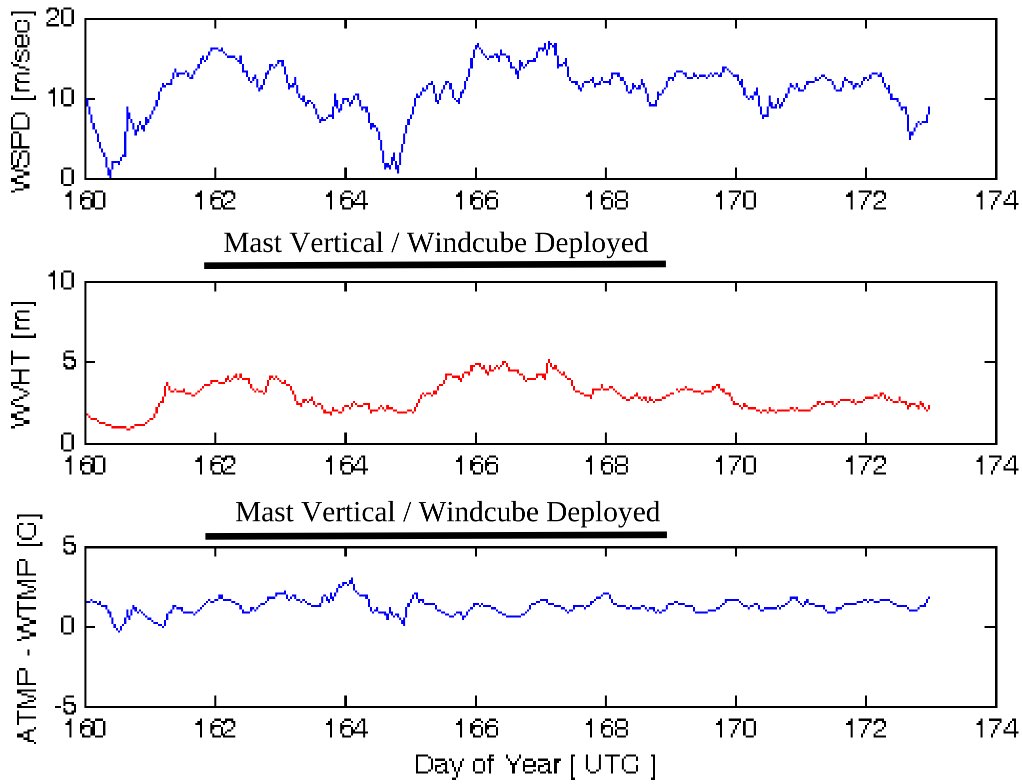

Figure 2 : NDBC Buoy 46013 data for conditions when R/P FLIP was at the HiRes site. The timeline shows when the UCI mast was vertical and Windcube was deployed.

The forcing of surface waves by the wind and the response of the wind to waves has practical implications in air-sea interactions. For this experiment we had several measurements of the wave height along the port boom side of R/P FLIP. Directly under the mast there was a resistance wave wire, at ~2m away from mast there was a wave laser (IML500_1; provided by SIO), at ~10m another wave laser (ILM500_2; provided by SIO), and at ~8m a wave radar was placed. Figure 3 shows a 15-minute sample of data collected from three instruments which shows good agreement.

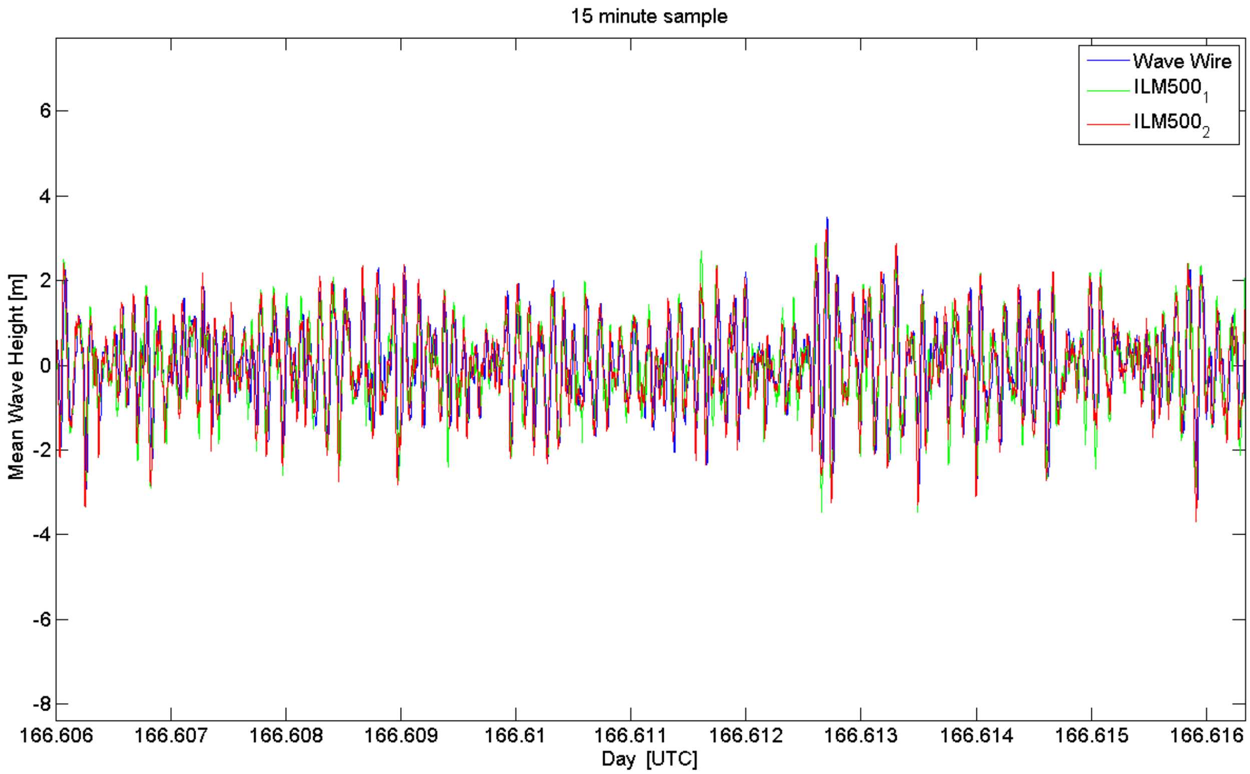

Figure 3 : Sample wave height data from 3 instruments along boom port of FLIP nearby UCI Mast.

For measurements within the MABL region of 2-30m, the existing UCI Meteorological Mast (Figure 4) was deployed on the new port boom of FLIP. The new boom provides double the capacity of the old boom (800 lb load at the end). Figure 4 shows the density of instruments deployed during the HiRes.

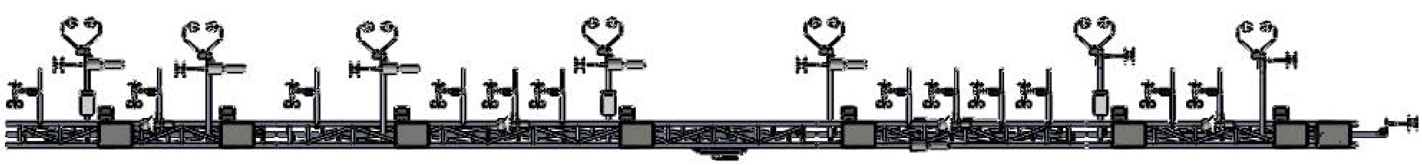

Figure 4 : Horizontal view of the UCI MET Mast with 21 levels of instrumentation for HiRes.

The UCI meteorological mast consists of 4 parts, 3-10ft sections and 1-20ft section. The 20ft section in the middle includes the hinge point. When fully assembled the overall length of the mast is 50ft, which will account for the intermediate region of the MABL. The lists of sensors, analog and serial, levels on the mast, and times of measurement (DOY UTC) are shown in the following three tables.

MAST LEVELS

Level	[ ]	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Distance to Water	[m]	1.51	2.93	3.41	3.95	4.76	5.34	5.88	6.38	6.92	7.81	9.00	10.30	10.83	11.36	11.95	12.84	13.60	14.82	15.38	16.19	16.72

ANALOG DATA

Instrument	Serial #	Level	Measurement	Variable	JD Start [UTC]	JD End [UTC]
Heinmann	KT19	Boom	^{o}C	IRSST	159194742	170120410
Krypton	KH20	12	^{o}C	krypton	163205505	170120410
RMY01	15550	3	s,d	RMY01s, RMY01d	161042259	170120410
RMY02	15553	4	s,d	RMY01s, RMY01d	161042259	170120410
RMY03	15557	6	s,d	RMY01s, RMY01d	161042259	170120410
RMY04	15551	8	s,d	RMY01s, RMY01d	161042259	170120410
RMY05	15549	9	s,d	RMY01s, RMY01d	161042259	170120410
RMY06	15552	13	s,d	RMY01s, RMY01d	161042259	170120410
RMY07	15560	15	s,d	RMY01s, RMY01d	161042259	170120410
RMY08	15556	17	s,d	RMY01s, RMY01d	161042259	170120410
RMY09	15559	19	s,d	RMY01s, RMY01d	161042259	170120410
RMY10	15558	21	s,d	RMY01s, RMY01d	161042259	170120410
Sonic3D	1830	2	u,v,w,c	cs01u,cs01v...etc	161223128	170120410
Sonic3D	875	5	u,v,w,c	cs02u,cs02v..etc	0	0
Sonic3D	878	7	u,v,w,c	cs03u,cs03v...etc	161223128	170120410
Sonic3D	200	10	u,v,w,c	cs04u,cs04v...etc	161223128	170120410
Sonic3D	1003	14	u,v,w,c	cs05u,cs05v..etc	161223128	170120410
Sonic3D	197	16	u,v,w,c	cs06u,cs06v...etc	161223128	170120410
Sonic3D	876	18	u,v,w,c	cs07u,cs07v...etc	161223128	170120410
VREF	5V	------	volts	csJu	156202739	159194742
VREF	5V	------	volts	ref1	159194742	170120410
VREF	-2.5V	------	volts	ref3	161223128	170120410
VREF	-5V	------	volts	ref2	161223128	170120410
WaveWire	SIO Pinkel	Boom	Hs	waves3	164212934	165009473
WaveWire	SIO Pinkel	Mast	Hs	waves4	164154937	167100238

SERIAL DATA

Instrument	Serial #	Level	Measurement	Extension	JD Start [UTC]	JD End [UTC]
202BG	94830	10	P	.202BG94830	162023129	170120410
202BG	95680	12	P	.202BG95680	162023129	170120410
202BG	94832	16	P	.202BG94832	162023129	170120410
202BG	94836	18	P	.202BG94836	162023129	170120410
202BG	81595	20	P	.202BG81595	162023129	170120410
202BG	81587	Boom	P	.202BG81587	166015532	170120410
Boeing	CMIGITS III	22	Lat,Lon,Alt,Ax,Ay,Az	.Boeing	162155247	170120410
FLIP Gyro	flipgyro	------	Heading	.GyroSerial	156194739	170120410
HartA12043	CH 5 - 145	11	Ω	.HartA12043	165182913	170120410
HartA12043	CH 7 - 2901	water	Ω	.HartA12043	165182913	170120410
HartA12043	CH 6 -2902	water	Ω	.HartA12043	165182913	170120410
HartA12043	CH 8 - 150	water surf	Ω	.HartA12043	165182913	170120410
HartA12044	CH 3 - 152	3	Ω	.HartA12044	165182913	170120410
HartA12044	CH 2 - 144	8	Ω	.HartA12044	165182913	170120410
HartA12044	CH 4 - 142	15	Ω	.HartA12044	165182913	170120410
HartA12044	CH 1 - 148	19	Ω	.HartA12044	165182913	170120410
Leosphere	WindCube	Face Boom	u,v,w,d @ Alt	.sta, .rtd,.dsp	163094428	170120001
Met3A	96191	10	P, T	.Met3A96191	162023129	170120410
Met3A	80825	12	P, T	.Met3A80825	162023129	170120410
Met3A	81424	16	P, T	.Met3A81424	162023129	170120410
Met3A	94129	18	P, T	.Met3A94129	162023129	170120410
Met3A	96187	20	P, T	.Met3A96187	162023129	170120410
Met3A	94128	Boom	P, T	.Met3A94128	165074118	170120410
Met4A	110597	1 , 7	P, T	.Met4A110597	162023129	170120410
Met4A	110596	2 , 9	P, T	.Met4A110596	162023129	170120410
Met4A	110598	5 , 10	P, T	.Met4A110598	162023129	170120410
Met4A	110594	Boom	P, T	.Met4A110594	165074118	170120410
NI GPS	NI-6682	------	Lat,Lon,Alt, tms	.GPSPosition	156194739	170120410
Oconner	waveradar	Boom	Hs	.Oconner	159194742	167022856
Oxford	RT3102	Boom	Lat,Lon,Alt,Ax,Ay,Az	.Oxford	167022856	170120410
Sonic3D	1830	2	u,v,w,c	.cs1830	162023129	170120410
Sonic3D	878	7	u,v,w,c	.cs0878	162023129	170120410
Sonic3D	200	10	u,v,w,c	.cs0200	162023129	170080410
Sonic3D	537	11	u,v,w,c	.cs0537	162023129	170120410
Sonic3D	540	12	u,v,w,c	.cs0540	162023129	170120410
Sonic3D	1003	14	u,v,w,c	.cs1003	162023129	170120410
Sonic3D	197	16	u,v,w,c	.cs0197	162023129	170120410
Sonic3D	876	18	u,v,w,c	.cs0876	162023129	170120410
Sonic3D	539	20	u,v,w,c	.cs0539	162023129	170120410
Sonic3D	538	Boom	u,v,w,c	.cs0538	165074118	170120410
Sonic3D	536	Boom	u,v,w,c	.cs0536	165074118	170120410
Wave Laser 1	ILM500	Boom	Hs	.ILM500	165074118	165152126
Wave Laser 1	ILM500	Boom	Hs	.ILM500_1	165182913	170120410
Wave Laser 2	ILM500	Boom	Hs	.ILM500_2	165182913	170120410

For the upper region of the MABL, the Windcube manufactured by Leosphere, of France, was deployed on the Face Boom of R/P FLIP. It is contained in a small weather-proof container with the eye-safe beam pointing upwards. The measurement is based on the backscatter from particles in the air (aerosols) along four beams. The received signals are processed into the horizontal wind vector at heights from 40m – 240m depending on the strength of the aerosol return. Figure 5 is picture taken from R/P FLIP during the June 2010 HiRes DRI of the Windcube deployed on the face boom.

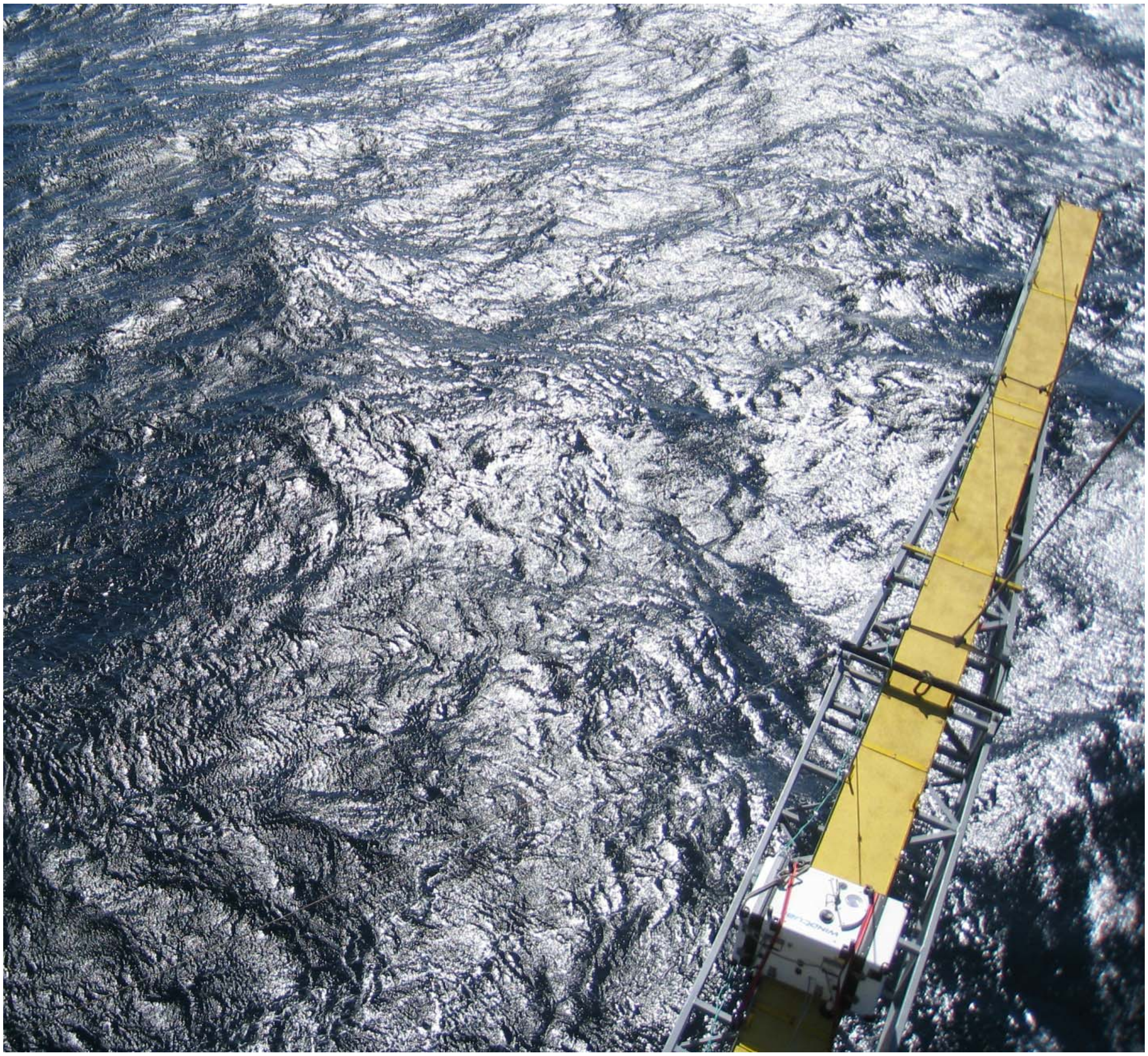

Figure 5 : Windcube mounted 7m above the sea surface on the face boom of R/P FLIP.

Figure 6 (top) shows a sample data set of conditions in the field, during a two-day interval where wind speed dropped dramatically and then increased. Also shown in Figure 6 (bottom) are Windcube wind profiles for the days of decrease and increase, which are shown in red and blue, respectively. When the wind speed was decreasing, the profile exhibits a minimum at the top of the MABL and reverse shear underneath. When the wind speed was increasing, the profile exhibits a maximum at the top of the MABL and positive shear underneath.

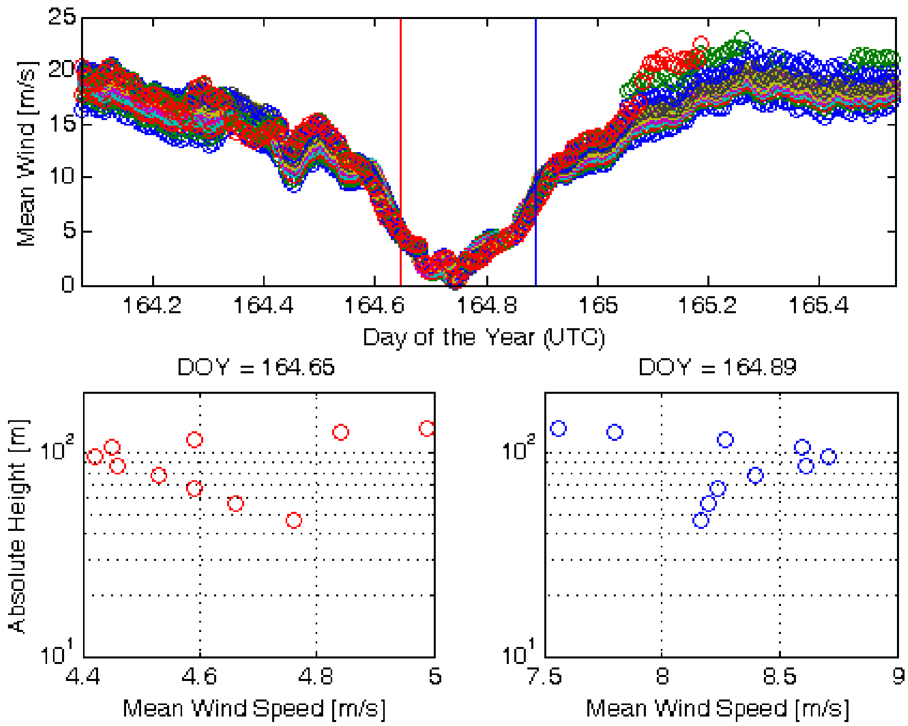

Figure 6 : Velocity profiles above R/P FLIP as measured by Leosphere Windcube from a two-day sample.

Figure 7 shows a sample wind profile from the mast and Wincube, for a day of high-wind day (DOY= 166) which extends from the 5m – 250m above the water. The profile along the mast exhibits the well-known semi-logarithmic surface layer behavior, while curvature occurs above.

Figure 8 shows the wind stress profile calculated from the sonic anemometers along the mast, for DOY =166. The usual surface layer assumption is that stress is constant with height, clearly not found for this case. To test that the reliability of the stress measurements, we computed the cospectra of the turbulence wind components whose integral is the covariance, the kinematic wind stress. Figure 9 (top) shows the raw cospectrum and Figure 9 (bottom) shows the running integral which asymptotes to the stress at low frequencies. The value of the stress is reasonable and represents drag coefficient 0.0016.

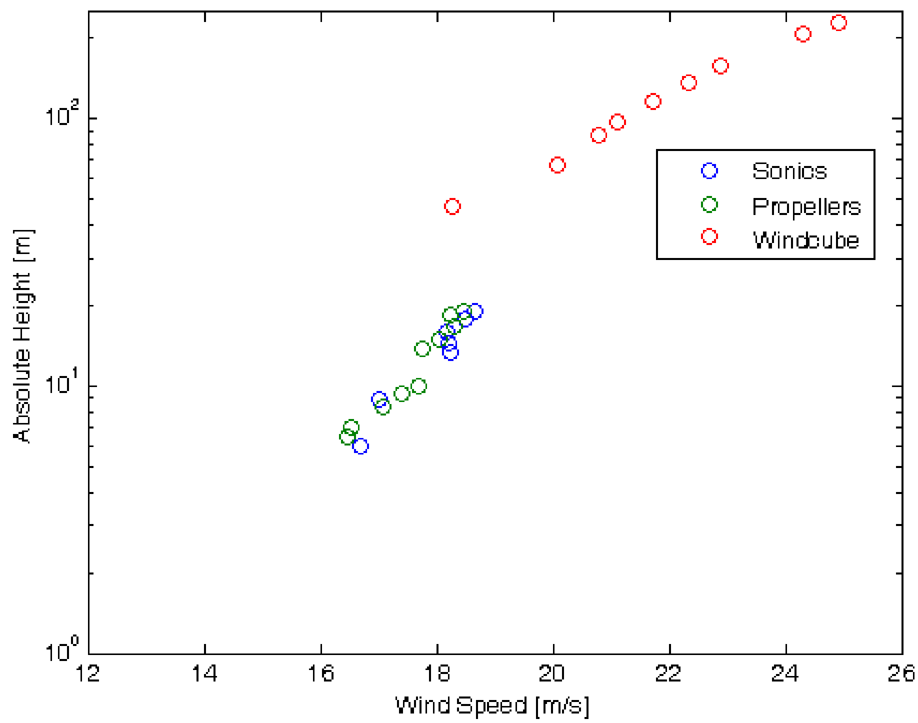

Figure 7 : Mean wind velocity profile constructed from UCI mast and Windcube for a high-wind day of year 166.

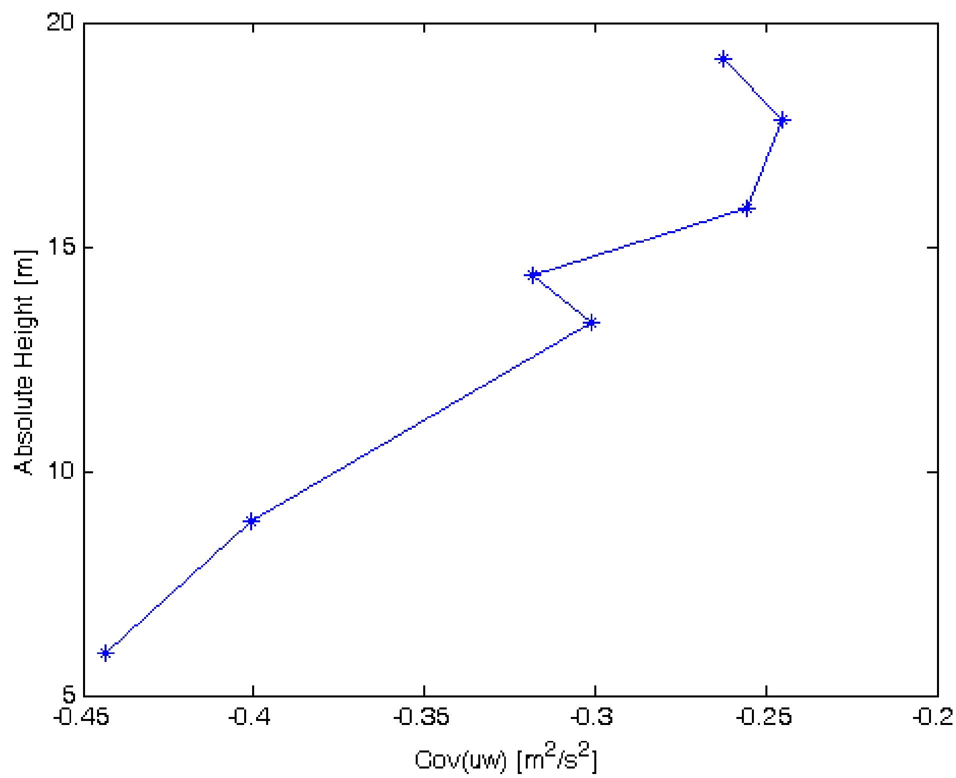

Figure 8 : Wind stress profile for DOY = 166, from sonics on UCI mast.

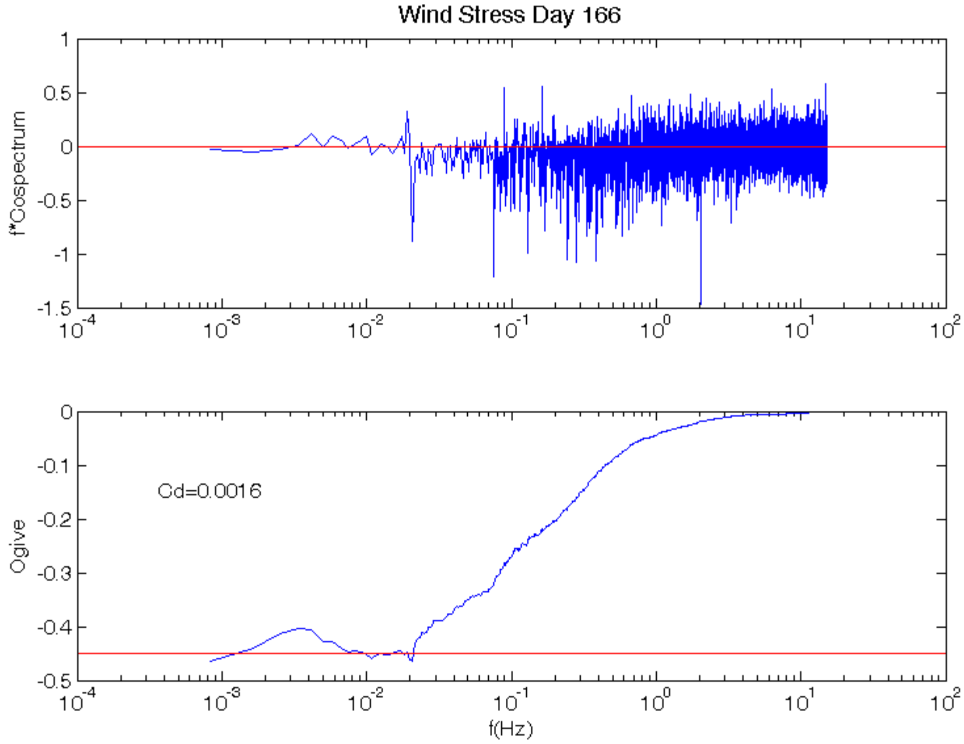

Figure 9 : Wind stress calculations for high wind case (DOY= 166).

IMPACT/APPLICATIONS

The analysis of the unique data set obtained in HiRes will provide new insight into the wind-wave-turbulence physics over ocean waves, including breaking.

TRANSITIONS

The Windcube lidar proved a reliable instrument for obtaining the wind profile from 47m to ~200m, which may have application in helicopter and aircraft operations at low level over the sea.

RELATED PROJECTS

None